OFFICIAL PUBLICATIONS
OF CORNELL UNIVERSITY

VOLUME VI NUMBER 6

ANNOUNCEMENT OF THE COLLEGE OF CIVIL ENGINEERING 1915-16

MARCH 1, 1915
PUBLISHED BY CORNELL UNIVERSITY
ITHACA, NEW YORK

This announcement is intended to give detailed information to prospective students in the College of Civil Engineering of Cornell University.

For general information concerning the University and its various colleges, the requirements for admission, etc., the General Circular of Information should be consulted. This and the other Official Publications of Cornell University are listed on the last page of the cover of this pamphlet. Any one of the informational publications there mentioned will be sent gratis and post-free on application to the Secretary of Cornell University, Ithaca, New York.

CALENDAR

First Term 1915–16

Sept. 17,	Friday,	Entrance examinations begin.
Sept. 27,	Monday,	Academic year begins. Registration of new students. Scholarship examinations begin.
Sept. 28,	Tuesday,	Registration of new students.
Sept. 29,	Wednesday,	Registration of old students.
Sept. 30,	Thursday,	Instruction begins. President's annual address to the students.
Oct. 2,	Saturday,	Registration, Graduate School.
Oct. 19,	Tuesday,	Last day for payment of tuition.
Nov.		Thanksgiving Recess.
Dec. 22,	Wednesday,	Instruction ends } Christmas Recess.
Jan. 5,	Wednesday,	Instruction resumed }
Jan. 11,	Tuesday,	Founder's Day.
Jan. 29,	Saturday,	Instruction ends.
Jan. 31,	Monday,	Term examinations begin.

Second Term 1915–16

Feb. 12,	Saturday,	Registration, Undergraduates.
Feb. 14,	Monday,	Registration, Graduate School.
Feb. 14,	Monday,	Instruction begins.
Mar. 3,	Friday,	Last day for payment of tuition.
April 5,	Wednesday,	Instruction ends } Spring Recess.
April 13,	Thursday,	Instruction resumed }
May 27,	Saturday,	Navy Day.
June 7,	Wednesday,	Term examinations begin.
June 21,	Wednesday,	Commencement.

COLLEGE OF CIVIL ENGINEERING

FACULTY

Jacob Gould Schurman, D.Sc., LL.D., President.
Eugene Elwin Haskell, C.E., Dean of the College of Civil Engineering and Professor of Experimental Hydraulics.
Charles Lee Crandall, C.E., M.C.E., Professor of Railroad Engineering.
Irving Porter Church, C.E., M.C.E., Professor of Applied Mechanics and Hydraulics, in charge of the College Library.
Henry Sylvester Jacoby, C.E., Professor of Bridge Engineering.
Henry Neely Ogden, C.E., Professor of Sanitary Engineering.
John Thomas Parson, Assistant Professor of Drawing, in charge of the Photographic and Drawing collections.
Ernest William Schoder, B.S., Ph.D., Assistant Professor of Experimental Hydraulics, in charge of the Hydraulic Laboratory.
Fred Asa Barnes, C.E., M.C.E., Assistant Professor of Railroad Engineering.
Ora Miner Leland, B.S. (C.E.), Assistant Professor of Geodesy and Astronomy, in charge of the Department of Topographic and Geodetic Engineering.
Miles Albion Pond, Ph.B., Assistant Professor of Civil Engineering, in charge of Descriptive Geometry.
Francis Joseph Seery, S.B., Assistant Professor of Civil Engineering.
Ernest William Rettger, A.B., Ph.D., Assistant Professor of Applied Mechanics.
Sidney Gonzales George, C.E., Assistant Professor of Applied Mechanics and Secretary of the College Faculty.
Charles Leopold Walker, C.E., Assistant Professor of Sanitary Engineering.
Kenneth Bertrand Turner, C.E., M.C.E., Assistant Professor of Hydraulics.
Adelbert Philo Mills, B.S. (C.E.), M.S. (C.E.), Assistant Professor of Testing Materials.
Paul Halladay Underwood, C.E., Assistant Professor of Topographic and Geodetic Engineering.
Leonard Alexander Lawrence, B.S., Instructor in Surveying.
John Clarence McCurdy, B.S., C.E., Instructor in Surveying.
Earle Nelson Burrows, C.E., M.C.E., Instructor in Bridge Engineering.
Julius Frederick Brauner, C.E., Instructor in Civil Engineering.
Walter Lichtenthaeler Conwell, C.E., Instructor in Civil Engineering.
Leonard Church Urquhart, C.E., Instructor in Bridge Engineering.
Ernest Charles White, C.E., Instructor in Civil Engineering.
William Edward Beitz, C.E., Instructor in Civil Engineering.
Carl Crandall, C.E., Instructor in Civil Engineering.
Harry William Butts, C.E., Instructor in Materials Laboratory.
Carl H. Knoettge, B.A., B.S. in C.E., Instructor in Bridge Engineering.
Herbert Vinton Hotchkiss, B.S in C.E., Instructor in Civil Engineering.
Edward Ray Stapley, C.E., Instructor in Civil Engineering.

Gertrude Marsh Sanford, College Librarian.
Helen R. Lynch, Secretary to the Dean.
Lena K. Haylett, College Stenographer.
Clinton D. Cass, College Mechanician.

GENERAL PLAN OF STUDIES

The courses of preparatory and professional studies have been planned with a view to laying a substantial foundation for the general and technical knowledge needed by practitioners in civil engineering so that our graduates, guided by their theoretical education and as much of engineering practice as can well be taught in schools, may develop into useful investigators and constructors.

The facilities for instruction and for advanced investigations are believed to be thorough and efficient. Laboratory work is required in chemistry, mineralogy, geology, mechanics, and testing materials. In addition to the special library and laboratories of the College, all the other libraries, collections, and laboratories of the University are open to civil engineering students.

The work of the student comprises an extended course in mathematics, mechanics and graphics, and in their applications to engineering. The object aimed at is to give as thorough a preparation as possible for the general purposes of the profession in the following subjects: the survey, location, and construction of roads, railroads, canals, and water works; the construction of foundations under water and on land, and of superstructures and tunnels; the survey, improvement, and protection of coasts, and the regulation of rivers, harbors, and lakes; the astronomical determination of geographical coördinates for geodetic and other purposes; the application of mechanics, graphical statics, and descriptive geometry to the construction of the various kinds of arches, girders, roofs, trusses, suspension and cantilever bridges; the drainage of districts, sewerage of towns, and the irrigation and reclaiming of land; the design, construction, application, and tests of hydraulic and electric motors and steam engines; the preparation of drawings, plans, and specifications, and the proper inspection and tests of the materials used in construction. Instruction is given in engineering economy, finance, and jurisprudence. The latter subject deals in an elementary manner with the questions of easements and servitudes, and the ordinary principles of the laws of contracts and riparian rights.

The building occupied by the College of Civil Engineering is Lincoln Hall, a substantial brown stone structure, two hundred feet long and seventy feet wide, especially designed for its purpose. In addition to the laboratories and museums, the building contains the working library of the College, aggregating about four thousand volumes, reading rooms, class rooms, and draughting rooms. The astronomical and portions of the geodetic equipment are housed in the Fuertes Observatory* containing all the instruments required for determining time, latitude, longitude, and azimuth. Several of the instruments are duplicates of those used by the United States Coast and Geodetic Survey. The large hydraulic laboratory with its buildings and equipment is located at the Fall Creek gorge, within a short distance of the College building.

LABORATORIES

The Civil Engineering Laboratories are located in three distinct buildings and comprise the following:

1. **The Cement Laboratory.** This laboratory contains machines for tension tests, compression machines of from two to two hundred tons capacity, and an

*See p. 7.

impact machine. For direct experiment with cement there is also provided a large number of tension and compression briquette moulds, a water tank with capacity for the storage of three thousand briquettes, a moist oven with a capacity of seven hundred briquettes, and three drying ovens; scales, slates, and plate-glass mixing tables, thermometers, a Bunsen pump for determining permeability, several sets of apparatus for measuring linear and volume changes during setting, and apparatus for determining specific gravity, normal consistency, and time of set, and constancy of volume by normal and accelerated tests; also standard sieves for determining fineness, and apparatus for determining voids in sand and stone.

2. **The Testing Laboratory** for materials of construction and for full sized members, joints, and structures. The equipment of this laboratory includes: a Riehlé 400,000 lb. testing machine with a capacity for beams and girders up to 19 inches in width and 18 feet in length, and for specimens in tension and compression up to 12 feet in length; a Riehlé 100,000 lb. testing machine, and an Olsen 50,000 lb. machine; an Olsen 10,000 lb. wire testing machine; a Thurston autographic torsion testing machine; a Riehlé torsion testing machine of 60,000 inch-pounds capacity, for testing rods and shafts up to one and a half inches in diameter and six feet in length; a Riehlé 5,000 lb. transverse load testing machine for flexural tests of bars of wood and metal up to four feet in length; an Amsler-Laffon compression testing machine; a standard Page impact machine for tests of road material; a Riehlé grinder for stone specimens; a standard Deval machine for abrasion tests of road material; and a standard rattler for paving brick.

The equipment also includes a set of torsion clinometers reading to single minutes, for use with the Riehlé torsion machine; a Henning extensometer for tension tests of metals, and two self-indicating dial extensometers with fittings which adapt them for use in testing steel or iron tension or compression specimens, and also for testing full-sized concrete beams and columns and for tests of wire. The Martens mirror extensometer is also available. Knock-down forms are provided for the making of large concrete beams and columns.

3. **The Highway Laboratory.** The rock testing section, which includes a Deval machine, Page impact machine for the toughness test, impact machine for the cementation test, ball mill, core drill, diamond saw, grinding lap, Dorry machine, briquette molding machine, and a rattler for brick testing, is located in the basement of Lincoln Hall.

Plans for a special building of fireproof construction have been prepared for the bituminous laboratory. This structure will be ready for the opening of the University in September 1915. The equipment, at present, includes an Engler viscosimeter, drying ovens, a New York State Board of Health oil tester, balances, a New York Testing Laboratory penetrometer, molds for the flow test, etc., bitumen extractors, and equipment for distillations. By the time the laboratory is ready it is hoped that additional equipment will be available.

4. **The Hydraulic Laboratory.** In addition to the usual equipment for the ordinary laboratory experiments, the unique location and construction of this laboratory render practicable, investigations requiring relatively large flows of water. The water supply is obtained from Fall Creek with a watershed of 126 square miles. Beebe Lake, a pond of about 20 acres, has been formed by

the construction of a concrete dam 26 feet high, with a spillway crest length of 130.5 feet. At one end of the dam there is an additional flood spillway 141.5 feet long. A rectangular canal 420 feet long and 16 feet wide is supplied from Beebe Lake through six headgates for controlling the amount of flow. The upper portion of the canal is 17.7 feet deep and the lower portion is 10 feet deep. In this canal are two sharp crested weirs 16 feet long over which discharges as large as 400 cubic feet per second may be passed.

A branch canal 6 feet wide leads from the lower end of the large 16-foot canal into the upper portion of the laboratory building which is built against the cliff of the gorge. This branch canal is supplied directly from Beebe Lake by means of a 48-inch cast iron pipe line with a short 30-inch branch at its lower end. A 30-inch valve controls the flow from the 48-inch pipe into the 6-foot canal. The 6-foot canal within the laboratory building discharges either to waste into the pool below Triphammer Falls (a sheer drop of 60 feet) or into the upper end of a steel standpipe 6 feet in diameter and 60 feet high. A suitable mechanism causes an instantaneous diversion of discharges as large as 60 cubic feet per second from the waste flume into the standpipe or vice versa. The 6-foot standpipe is provided at the bottom with a 36-inch discharge valve operated by hydraulic pressure. There is a float gauge indicating accurately the height of the water surface in the standpipe, which is used either as a measuring tank or as a supply reservoir.

The lower portion of the large 16-foot canal, 350 feet long between weirs, is used for measurements with floats and current meters. An electrically operated car spans this canal and is used for rating the current meters. Models of dams may be built in the canal and the flow over them investigated with precision.

There is an outdoor equipment for pipe-flow experiments with pipes as large as 6 inches in diameter, with a concrete tank for precise measurements of flow. The 8-inch pipe line supplying the University filtration plant is available for experimentation, giving a head of 225 feet.

A concrete Cippoletti weir with steel edges and with a crest length of 16 feet, and a depth of notch of 6.5 feet is built in the gorge below Beebe Lake dam and serves to measure the creek flow to calibrate the dam and the 5-foot flood gate in the dam.

Part of the equipment of the University power plant may also be used for certain kinds of hydraulic experimentations. The available head here is 135 feet.

Although the laboratory needs still further additions to its very expensive equipment, the utility of this plant has been demonstrated by calls from all parts of the country for the performance of experiments of great importance. Among these may be mentioned the valuable results obtained for the United States Deep Waterways Commission, the Michigan Lake Superior Power Company, the City of New York in connection with its water supply, and for the United States Geological Survey.

5. **The Sanitary Laboratory.** This laboratory provides facilities for the physical, chemical, bacteriological, and biological analyses of water and sewage; and for the performance of such other tests as will acquaint the student with current practice as affecting the control and operation of the various types of water purification and sewage disposal plants.

The equipment includes microscopes and the necessary accessories for complete bacteriological and biological examinations of water; an autoclave, a hot-air sterilizer, a 37½° and two 20°C. incubators, a chemical balance, a United States Geological Survey turbidity rod and color standards; four experimental sand filters, fitted with loss of head gauges, and providing for a total depth of sand and water of nine feet, for determining the rate and efficiency of operation of sand filters, as well as various types of sewage nozzles. The laboratory is well equipped with such glassware, reagents, accessories, and apparatus as are needed for making the chemical analyses of water and sewage effluents.

6. **The Metric Laboratory** for the comparison of standards of length. The room is built with hollow walls, and the daily range of temperature can be kept within 1° F. It contains a four-meter comparator of the Repsold type, but with the beam supporting the two micrometer microscopes resting on piers independent of those supporting the bed or main framework. The cradle supporting the two bars under comparison can be moved laterally so as to bring first one and then the other under the microscopes by a crank outside of the case which protects the apparatus from sudden temperature changes due to the presence of the observer. The standard of length is a steel metal bar of the International type which has been compared with the International Standard at the Coast and Geodetic Survey Office. There is also a Rogers speculum metal decimeter and 4-inch scale combined, accurately divided and compared, and a 4-meter bar for subsidary standards.

Tonnelot and Boudin thermometers, standardized at the International Bureau in Paris, form the basis for temperatures. A 4-foot comparator is provided for the study of leveling rods, and a 100-meter field comparator for standardizing base line tapes. Repsold cut-off tubes are used to transfer from the underground monuments to the tapes under field conditions. The standard is a 50-meter invar tape the length of which has been determined with exceptional precision by the United States Bureau of Standards. A 100-foot tape comparator is located on the fourth floor of Lincoln Hall.

7. **The Photographic Laboratory** for reproducing the appearance of tested specimens, for the purposes of the lecture room, as an aid in topographic surveys, and for the distribution of reprints of the collection of progress photographs of engineering structures owned by the College.

The equipment includes a revolving or panoramic camera constructed by the mechanician of the College from patterns generously supplied by the inventor, Mr. G. W. Parsons. This is especially useful in topographic work since the entire view of 360° at a station can be included on a film 6 inches wide and about 70 inches long.

8. **The Fuertes Astronomical Observatory and Geodetic Laboratory** building has been removed to provide room for other construction. It contained computing rooms, a transit room with four piers, a clock room, and three domes. It is expected that the new building will be ready for occupancy in the fall of 1915.

The equipment includes a Howard mean time astronomical clock, Negus and Nardin sidereal chronometers, four chronographs, a Troughton and Simms transit, a Fauth transit, two Fauth zenith telescopes, a Troughton and Simms 12-inch altazimuth, a Fauth 10-inch altazimuth, a 4½-inch equatorial telescope with

position micrometer and helioscope, besides sextants, surveyors' transits, etc. The laboratory also contains a Mendenhall half-second pendulum apparatus for the determination of the acceleration of gravity,—the standard type used by the United States Coast and Geodetic Survey. For observations of terrestrial magnetism, a Kew magnetometer, a dip-circle, and a declinometer are available. In addition to the above, there are a level-trier, a dividing engine by the Société Genévoise, a small comparator for calibrating thermometers, a Fuess barometer, and the usual auxiliary instruments including clocks, collimators, micrometers, spherometer, meteorological instruments, etc.

Mechanician's Room. This room is used in connection with the laboratories for the construction of special apparatus and instruments and for the maintenance of the equipment. It is well supplied with tools and special machines for the purpose, and is in charge of a mechanician.

The Museums of the College of Civil Engineering contain the following collections: 1. The Muret collection of models in descriptive geometry and stone cutting. 2. The DeLagrave general and special models in topography and geognosy. 3. The Schroeder models in descriptive geometry and stereotomy with over 50 brass and silk transformable models made in the College after the Olivier models. 4. The M. Grund collection of bridge and roof details, trusses, and masonry structures, such as right, oblique, and annular arches and domes, and several intricate models in stone cutting, supplemented by similar models by Schroeder amd other makers. 5. A model railroad bridge of 25-foot span, one-fourth natural size, and a numerous collection of models of track details. 6. The Digeon collection of movable dams, artificial harbors, and working models in hydraulic engineering. 7. Working models of water wheels, turbines, and other water engines. 8. Several large collections of European and American progress photographs of engineering work showing the progress of construction, and many other photographs, blue-prints, models, and diagrams. 9. A collection of typical geodetic and surveying instruments of historical interest, including a secondary base-line apparatus made under the direction of the United States Coast and Geodetic Survey, a pair of base-bars constructed in this college, solar and magnetic compasses, levels, transits, theodolites, omnimeters, tacheometers, sextants, telemeters, altmeters, hypsometers, odometers, meteorological instruments, etc., with a large number of auxiliary and special instruments such as planimeters, pantographs, elliptographs, calculating devices and computing machines.

REQUIREMENTS FOR ADMISSION

(Candidates for admission should consult the General Circular of Information, which will be sent post-free on application to the Secretary of Cornell University, Ithaca, New York. All applications for admission to the freshman class should be addressed to the Registrar.)

The subjects that may be offered for admission to the College of Civil Engineering are named in the following list and the figure in parenthesis following each subject indicates its value expressed in units and shows the maximum and minimum amount of credit allowed in the subject. A unit represents five prepared recitations a week for one year in a study.

1a. English A..... (2)
1b. English B..... (1)
2a. First Year Greek..... (1)
2b. Second Year Greek..... (1)
2c. Third Year Greek..... (1)
3a. First Year Latin..... (1)
3b. Second Year Latin..... (1)
3c. Third Year Latin..... (1)
3d. Fourth Year Latin..... (1)
4a. First Year German..... (1)
4b. Second Year German..... (1)
4c. Third Year German..... (1)
5a. First Year French..... (1)
5b. Second Year French..... (1)
5c. Third Year French..... (1)
6a. First Year Spanish..... (1)
6b. Second Year Spanish..... (1)
6c. Third Year Spanish..... (1)
7a. First Year Italian..... (1)
7b. Second Year Italian..... (1)
7c. Third Year Italian..... (1)
8a. Ancient History.....(½–1)
8b. Modern History.....(½–1)
8c. Am. History, Civics.....(½–1)
8d. English History.....(½–1)
9a. Elementary Algebra..... (1)
9b. Intermed. Algebra..... (½)
9c. Advanced Algebra..... (½)
9d. Plane Geometry..... (1)
9e. Solid Geometry..... (½)
9f. Plane Trigonometry..... (½)
9g. Spher. Trigonometry..... (½)
10. Physics ..... (1)
11. Chemistry ..... (1)
12. Physical Geography.....(½–1)
13. Biology* ..... (1)
14. Botany*.....(½–1)
15. Zoology* .....(½–1)
16. Agriculture.....(½–1)
17. Drawing .....(½–1)
18. Manual Training..... (1)
19. Any high school subject or subjects not already used .....(½–1)

Four Year Course

For admission to the regular course, the applicant must offer fifteen units from the above list of entrance subjects, as follows: English (3), history (1), elementary algebra (1), intermediate algebra (½), plane geometry (1), solid geometry (½), advanced algebra (½), plane trigonometry (½), either Greek, Latin, French, German, Spanish, or Italian (3†), and elective (4††). Applicants will be admitted, however, who offer fifteen entrance units as follows: English (3), history (1), elementary algebra (1), plane geometry (1), either Greek, Latin, French, German, Spanish, or Italian (3†), and elective (6††); but they will be required to take solid geometry, advanced algebra and plane trigonometry in the University in addition to the work prescribed in the regular four year course. This will necessitate attendance for more than four years unless some of the work is taken during the Summer Sessions.

Five Year Course

For admission to the five year course, the applicant must offer fifteen entrance units as follows: English (3), history (1), elementary algebra (1), intermediate algebra (½), plane geometry (1), either Greek, Latin, French, German, Spanish, or Italian (3†) and elective (6††).

Six Year Course

For admission to the six year course, the requirements are those of the College of Arts and Sciences, in which college the student is registered during the first four years.

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*If an applicant has counted Biology (1) he may not also offer Botany (½) or Zoology (½).
†It is recommended that the language requirement be satisfied by French or German.
††It is strongly recommended that at least three of these four elective units be offered in language and history.

ADMISSION FROM OTHER COLLEGES

A student who, having already attended some college or university, desires to enter one of these courses should file with the Registrar of Cornell University, on an official blank to be obtained from him, a formal application for admission, along with an official certificate from the college or university already attended, of his honorable dismissal; his entrance examinations in detail; his terms of attendance and the amount of work that he has completed; and a detailed statement of the courses pursued. He should send also a catalogue of the institution, writing on it his name and marking the entrance requirements that he has satisfied and each subject that he has completed.

ADMISSION AS SPECIAL STUDENTS

College graduates over twenty-one years of age, who wish to pursue advanced work without being candidates for a degree, may be admitted without entrance examinations. See General Circular of Information.

PRIZES

For scholarships and prizes, see the General Circular of Information, and the Pamphlet on Prizes, which may be obtained on application to the Secretary of the University.

The Fuertes Medals, founded by Professor E. A. Fuertes and consisting of two gold medals, each of the value of one-half the amount of the income provided by the endowment fund will be awarded under the following conditions:

One of these medals will be awarded annually by the University Faculty to the student in the College of Civil Engineering, who may be found, at the end of the first term of his senior year, to have maintained the highest degree of scholarship in the subjects of his course, provided he has been in attendance in the University for at least one and one-half years; and the other medal will be awarded annually by the Faculty to that graduate of the College of Civil Engineering who may write a meritorious paper upon some engineering subject tending to advance the scientific or practical interests of the profession of the civil engineer. It is desired that papers be presented on or before April 15th. If a paper is presented in a printed form, it will not be received if it has been printed earlier than the next preceding April 15th.

Neither medal shall be awarded unless it appears to the Faculty of the College of Civil Engineering that there is a candidate of sufficient merit to entitle him to such distinction. Candidates will be nominated to the University Faculty by the College of Civil Engineering annually.

The Charles H. Baker Public Speaking Prizes, founded by Charles H. Baker, a graduate of the College of Civil Engineering of the class of 1886, consisting of $100 and $20 respectively, are awarded annually to those members of the junior and senior classes in the College of Civil Engineering and Architecture, who may be selected after competitive trial, as especially proficient in public speaking. The orations delivered in competition for these prizes are to be original compositions on technical subjects. In making the awards both the character of the argument and the manner of delivery will be considered.

The William C. Seidell Book Fund of $1,000, founded by Gerrit S. Miller. The income to be used for the purchase of books for poor young men who are working their way through the College of Civil Engineering, is paid by the Treasurer of the University upon the recommendation of the Dean of the College, preference being given to members of the freshman class.

COURSES LEADING TO THE DEGREE OF CIVIL ENGINEER

The registration of new students will take place from 9 a. m. to 4 p. m., Monday and Tuesday, September 27 and 28, 1915. Seniors, juniors, and sophomores in good standing, may register in the College between 9 a. m. and 4 p. m. on Tuesday and Wednesday, September 28 and 29, 1915.

A student must register for at least 12 hours each term.

The required courses in mathematics, physics, chemistry, geology, and political economy are given in the College of Arts and Sciences; for a description of these courses see page 14 of this announcement. The required work in electrical engineering and steam machinery is given in Sibley College; for a description of these courses see page 17 of this announcement.

Four Year Course

Freshman Year	No. course	First term	Second term
Analytics	5	5	–
Differential and Integral Calculus	5	–	6
Physics	2	5	–
Physics	7	–	3
Chemistry	1	–	6
Descriptive Geometry	1	2	3
Drawing	2	2	–
Elementary Surveying	10	3	–

In addition to the above the required Military Drill must be taken.

During the first term there will be given to the freshmen (but without credit) a course of weekly lectures devoted to a general survey of the field of civil engineering. Attendance at these lectures is obligatory.

Sophomore Year	No. course	First term	Second term
Geology	31	3	3
Mechanics of Engineering	20	5	5
Materials Laboratory	22	2 or 0	0 or 2
Drawing	4	1 or 3	3 or 1
Advanced Surveying	11	2	4
Materials of Construction	25	3 or 0	0 or 3
Physics	14	0 or 2	2 or 0
Engineering Calculations	21	2	–
Summer Survey (five weeks in June and July)	13	–	6

In addition to the above, three hours a week of either Military Drill or Physical Culture must be taken in the sophomore year.

The work of the junior and senior years consists of the studies of some one of the six groups shown in the tabulation here appended, viz.: (a) general; (b) geodetic; (c) hydraulic; (d) sanitary; (e) railroad; (f) bridge.

On registering at the opening of the junior year each student of that class shall elect a group which he is to take for the remaining two years of his course.

The general group is strongly recommended in the case of all students who have no urgent reasons for electing one of the other (special) groups.

JUNIOR YEAR

Course No.		Gen. (a) I–II		Geod. (b) I–II		Hyd. (c) I–II		San. (d) I–II		R. R. (e) I–II		Bridge (f) I–II	
51	Political Economy	3	3	3	–	3	–	–	–	3	3	3	3
60	Railroads	4	4	4	4	4	4	4	2	4	4	4	4
71	Bridges	4	4	4	4	4	4	4	–	4	4	4	4
23	Hydraulics	5	–	5	–	5	–	5	–	5	–	5	–
52	Municipal Engineering	–	3	–	3	–	3	–	3	–	3	–	3
29	Engineering Problems	–	2	–	2	–	2	–	2	–	2	–	2
14	Survey Computations and Mapping	2	2	2	2	2	2	–	4	2	2	2	2
50	Sanitary Biology	–	–	–	–	–	–	–	5	–	–	–	–
6	Chemistry	–	–	–	–	–	–	5	–	–	–	–	–
77	Concrete Construction	–	–	–	–	–	3	–	–	–	–	–	–
6	Public Speaking	–	–	–	2	–	–	–	–	–	–	–	–
64	Roads and Pavements	–	–	–	1	–	–	–	1	–	–	–	–
		18	18	18	18	18	18	18	17	18	18	18	18

SENIOR YEAR

Course No.		Gen. (a) I–II		Geod. (b) I–II		Hyd. (c) I–II		San. (d) I–II		R. R. (e) I–II		Bridge (f) I–II	
16	Advanced Topographic Surveying	–	–	2	–	–	–	–	–	–	–	–	–
17	Geodesy and Geodetic Laboratory	–	–	3	–	–	–	–	–	–	–	–	–
18	Geodetic Astronomy	–	–	–	3	–	–	–	–	–	–	–	–
26	Advanced Mechanics	3 or 3		–	–	–	–	–	–	3	–	–	–
30	Water Supply	3 or 3		3	–	3	–	3	–	3 or 3		–	3
31	Hydraulic Construction	–	–	–	3	–	3	–	–	–	–	–	–
32	Water Power Engineering	–	–	–	–	3	–	–	–	–	–	–	–
41	Hydraulic Measurements	–	–	–	–	3	–	–	–	–	–	–	–
42	Experimental Hydraulic Motors and Pumps	–	–	–	–	–	3	–	–	–	–	–	–
53	Purification and Control of Water Supplies	–	–	–	–	–	–	–	3	–	–	–	–
53a	Sewage and Water Purification	2	–	–	–	–	–	–	–	–	–	–	–
54	Sewerage Works	–	–	–	–	–	–	3	–	–	–	–	–
55	Sanitary Laboratory	–	–	–	–	–	–	–	3	–	–	–	–
61	Railroad Maintenance of Way	–	–	–	–	–	–	–	–	3	–	–	–
62	Railroad Operation and Management	–	–	–	–	–	–	–	–	–	3	–	–
64	Roads and Pavements	1 or 1		–	–	–	1	–	–	–	1	–	1
71	Structural Design	–	–	–	–	–	–	–	4	–	–	–	–
72	Reinforced Concrete Arch	–	–	–	–	–	–	–	–	–	–	–	3
73	Higher Structures	–	–	–	–	–	–	–	–	–	–	3	–
74	Masonry and Foundations	3 or 3		3	–	–	–	–	–	–	–	–	3
77	Concrete Construction	3 or 3		3	–	–	–	3	–	3 or 3		3	–
90	Specifications and Contracts	2 or 2		–	2	–	2	–	2	2	–	2	–
91	Engineering Design	3 or 3		–	3	–	3	3	–	–	3	–	3
92	Thesis	–	3	–	3	3	–	–	3	3	–	3	–
51	Political Economy	–	–	–	–	–	–	3	–	–	–	–	–
E12	Electrical Engineering	4	–	4	–	4	–	–	–	4	–	4	–
69	Chemistry: Water Analysis	–	–	–	–	–	–	3	–	–	–	–	–
P11	Steam Machinery	–	3	–	3	–	3	–	3	–	3	–	3
	Elective	3	–	–	–	–	3	–	–	–	3	3	–
		18	18	18	17	16	18	18	18	18	16	18	16

In the general group a senior may, with the approval of his class adviser, substitute three hours for advanced mechanics, or for masonry and foundations, or for both. Oratory course 1 would be an acceptable substitute.

Engineering design in the general group and in the geodetic group may be taken in any one of the other groups by approval of the head of the department concerned.

For the thesis, work in engineering design or in investigation may be substituted; but this substitution must be approved by the professor in charge of the group which the student has elected. For the general group the substitution must be approved by the class adviser and the department concerned.

Five Year Course

For those students who wish to cover a somewhat broader field than that of the four year course in Civil Engineering, a five year course has been arranged as given below.

First Year	No. course	First term	Second term
Solid Geometry, Trigonometry	1, 3	–	6
Advanced Algebra	2(E)	3	–
Chemistry	1, 6	6	5
Drawing	2, 4	2	4
Elective*		6	3
		17	18

Second Year	No. course	First term	Second term
Analytic Geometry	5	5	–
Calculus	5		6
Physics	2, 7	5	3
Descriptive Geometry	1	2	3
Elementary Surveying	10	3	–
Elective*		2	6
		17	18

In addition to the above, three hours a week of either Military Drill or Physical Culture must be taken in the Sophomore year.

[The student must also attend the general lectures on civil engineering already mentioned in connection with the freshman year of the four year course.]

The third, fourth and fifth years are the same as the second, third and fourth years of the four year course, respectively, excepting that in the third year of the five year course Drawing 4 will be replaced by Elective 3 hours in the second term.

A Six Year Course Leading to the Degree of Bachelor of Arts at the End of Four Years and of Civil Engineer at the End of Six Years

Seniors in good standing in the College of Arts and Sciences, who have been in actual residence at least six terms, exclusive of summer sessions, and have a credit of at least 90 hours, may be registered both in the College of Arts and Sciences and in the College of Civil Enginering.

In accordance with this provision the following suggestion is given for a six year course leading to the degrees of A.B. and C.E.

The following subjects are to be included in the course of study of at least 90 hours in the College of Arts and Sciences during the first three years of residence.

*Electives may be taken in any college of the University.

	No. course	First term	Second term
Analytic Geometry	5	5	–
Calculus	5	–	6
Physics	2, 7	5	3
Physics	10	1	1
Chemistry	1	6	(or 6)
Chemistry	6	5	(or 5)
Geology	31	3	3
Descriptive Geometry	1	2	3
Drawing	2	2	–
Elementary Surveying	10	3	–

The following subjects in Civil Engineering are to be taken during the fourth year, when registered in both colleges.

	No. course	First term	Second term
Political Economy	51	3	3
Drawing	4	3	1
Advanced Surveying	11	2	4
Mechanics of Engineering	20	5	5
Engineering Calculations	21	2	–
Materials Laboratory	22	–	2
Materials of Construction	25	–	3
Physics	14	2	–
Summer Survey (five weeks in June and July)	13		6

The work for the fifth and sixth years is to include the subjects of the junior and senior years of the general group of the four year course leading to the degree of Civil Engineer, except that course 51 in Political Economy should be replaced by electives.

Students desiring to take this course are recommended to confer with the deans of the faculties concerned.

GRADUATE STUDY AND ADVANCED DEGREES

The facilities for study and research offered by the various laboratories of this college are available for graduate students; they will also find among both the regular and the elective courses given in the College many that are suitable for graduate study.

The degrees of Master of Civil Engineering (M.C.E.) and of Doctor of Philosophy (Ph.D.) are granted upon fulfilment of the conditions prescribed by the Faculty of the Graduate School. See Announcement of the Graduate School.

COURSES OF INSTRUCTION

SUBJECTS GIVEN IN THE COLLEGE OF ARTS AND SCIENCES

Mathematics

Course 5 may not, without special permission, be taken simultaneously with any of the other courses.

1. **Solid Geometry.** Repeated in second term, credit three hours.

Open to all students, but designed especially for those who have entered with the minor requirements in mathematics and are preparing: (a) to teach mathe-

matics in the secondary schools; (b) to take up engineering work later in the course; (c) to specialize in chemistry or physics.

2 (E). **Advanced Algebra.** First term, credit three hours. Open to engineering students who have satisfied the entrance requirements in Intermediate Algebra. The work here covered is the equivalent of that required in this subject for entrance to the four year course.

3. **Plane Trigonometry.** Repeated in second term, credit three hours.

Open to all students, but designed especially for those mentioned under course 1.

5. **Analytical Geometry and Calculus.** Prerequisite courses, 1, 2, and 3, or their equivalent.

5 (1). Daily except Saturday, first term; credit five hours. Repeated in the second term.

5 (2). A continuation of the work of 5 (1). Daily, second term; credit six hours. Repeated in the first term of the following year.

Physics

2. **Introductory Experimental Physics.** Repeated in second term, credit five hours. Three lectures and two class-room periods each week.

Lectures. Professors NICHOLS, MERRITT and SHEARER, and Assistant Professor GIBBS.

Class-room work. Assistant Professor GIBBS and others.

Entrance physics is not accepted as an equivalent of this course.

7. **Introductory Physics.** Class-room work. Repeated in second term, credit three hours. Prerequisite, course 2 or course 3. Messrs. MURDOCK and MALLORY.

10. **Introductory Physical Experiments.** Either term or throughout the year, credit one to four hours a term. May be taken with or following course 2, or 3, or 6, or 7, or the equivalent. Assistant Professor BLAKER, and Messrs. MAYER, GIBSON, and POWER.

A shorter course of two hours covering properties of matter, heat, light, sound, magnetism, and electricity may be taken for one term, the student electing two laboratory periods a week; or the course may be extended over a year, one period a week being taken. A longer course of three or four hours may be elected covering the same ground as the two-hour course but more in detail, the work being done in one term or distributed over two terms.

14. **Physical Experiments.** Either term or throughout the year, credit one to eight hours a term. Prerequisite courses 2 and 7; or 2 and the three-hour course in 10; or the equivalent. May be taken by students who are taking courses 8 and 9. Assistant Professor RICHTMYER and Messrs. BROWN, GERMANN, GIBSON, KING, KNAPP, PERKINS and PIDGEON. Rockefeller 250–257.

Physical measurements, properties of matter, mechanics, heat, light, sound, magnetism, and electricity; the adjustment and use of instruments of precision. Results and errors are carefully discussed. Students in the College of Civil Engineering are required to take two hours.

Chemistry

1. **Introductory Inorganic Chemistry.** Lectures, recitations, and laboratory. Repeated in second term, credit six hours.

1a. Lectures. First term, Professor DENNIS and Mr. DAVIS. Second term, Professor BROWNE and Mr. DAVIS.

1b. Recitations (one hour a week to be arranged), and laboratory. Professors DENNIS and BROWNE.

Entrance credit in chemistry does not carry with it university credit in course 1. If a student entering the University from a preparatory school desires credit in course 1, he must pass an examination set by the Department of Chemistry. This examination is held both in New York City and in Ithaca on the same day in September as the entrance examination. University credit in course 1 that is obtained by passing this examination, does not carry with it entrance credit in chemistry.

Examinations for those who were unavoidably absent from the final examination in course 1 will be held at 2 p. m. on the day before instruction begins in the fall.

6. **Qualitative and Quantitative Analysis.** Repeated in second term, credit five hours. Prerequisite course 1. Dr. LEMON, and assistants.

Qualitative work: the properties and reactions of the common elements and acids and their detection in various liquid and solid mixtures.

Quantitative work: the preparation and use of volumetric solutions and work in elementary gravimetric analysis.

Examinations for those who were unavoidably absent from the final examination in course 6 will be held at 2 p. m. on the day before instruction begins in the fall.

Military Science

1. **Military Training and Instruction as Infantry.** Required for all first year men. Throughout the year; three hours per week; M, W, F, 4:45 P. M. Practical Instruction:—outdoors in fair weather, three hours per week; indoors in winter months, one hour per week. Theoretical instruction; winter months, two hours per week, covering our Military Policy and Military History, the value of military training to a man and to a nation, infantry drill regulations, theory of target practice, camp sanitation, field service regulations, personal hygiene, organization, theory and functions of various arms, field engineering and guard duty. Practical rifle practice on outdoor and indoor ranges.

Geology

31. **Practical Geology.** Throughout the year, credit three hours a term. Registration by special permission. Professor RIES. Lectures and laboratory work.

The practical application of geologic principles and the occurrence of such economic materials as are of importance to engineering students, the whole subject being treated with reference to their needs.

Political Science

51. **Elementary Economics.** Throughout the year, credit three hours a term. One lecture and two recitations a week. Assistant Professor BAUER.

A general introduction to economics; a prerequisite for most of the other courses in the field of political science. Section assignments will be arranged at the first lecture. Office at Goldwin Smith 260.

Public Speaking

6. **Public Speaking for Engineers.** Repeated in second term, credit two hours. M W, 12. Mr. ANDERSON.

Engineering students whose work permits, may take instead the more complete general course 1; or on completion of course 6, they may take course 1 in the second term for either two or three hours.

SUBJECTS GIVEN IN SIBLEY COLLEGE

P. 11. **Heat Engines and Auxiliaries (for Civil Engineers).** Required of all seniors in civil engineering. Second term only, credit three hours. Not open to Sibley students. Prerequisites Physics 2 and 7, (or the equivalent), Chemistry 1, C.E. 20. One lecture and two recitations a week. Elementary consideration of behavior of gases. Gas engines. Theory of vaporization. Study of boilers; types of boilers; advantages and disadvantages of various types. Action of vapors in cylinders; steam engines and turbines; parts and operation; types, advantages and disadvantages; application; steam consumption and efficiencies. Advantages of condensing; types of condensers; condenser pumps; condenser auxiliaries, cooling towers, ponds, etc. Pumps. Contractor's plants. Cost of power.

This course is recommended for all students who wish to obtain a general elementary knowledge of heat-power engineering without great technical detail. Assistant Professor ELLENWOOD, and Messrs. JONES and CLARK.

E. 12. **Essentials of Electrical Engineering for Civil Engineers.** Required of all seniors in civil engineering except those in the sanitary group. First term only, credit four hours. Two recitations and one laboratory experiment with report each week. The purpose of the course is four-fold: (1) to review and apply the fundamental physical principles involved in electrical engineering; (2) to familiarize the student with and give practice in the handling of electrical machinery; (3) to enable the student to choose the proper type of apparatus for any particular service demanded in ordinary elementary practice; (4) to enable the student to read intelligently electrical engineering literature. Messrs. H. W. BROWN, STEVENSON and PAGE.

SUBJECTS GIVEN IN THE COLLEGE OF CIVIL ENGINEERING

Descriptive Geometry and Drawing

1. **Descriptive Geometry.** Freshmen. Credit two hours first term, and three hours second term. A study of the representation of lines, planes, surfaces, and solids, and their inter-relations. Warped surfaces. A textbook is used and recitations are held upon the problems there stated or explained. A drawing period serves to allow the student to make drawings of original problems which are illustrations and applications of the problems in the book. Recitations, one hour a week. Original problems, two and one-half actual hours a week. Tangencies, intersections, shades and shadows, perspective. The intersections include various forms of the intersections of planes with surfaces and solids, of surfaces with solids, and of solids with solids. The work in shades and shadows includes shade lines on solids and the shadows of solids on planes and other solids. Original

problems are assigned for work in the drawing room. Recitations, two hours a week. Original problems, two and one-half actual hours a week. First term. Four sections in recitations, and six sections in problems. Second term. Six sections in recitations, and six sections in problems. Assistant Professor POND and Mr. HOTCHKISS.

2. **Drawing and Lettering.** Freshmen. Credit two hours. Six hours a week during first term. The work is sub-divided and is taken up in the following order: freehand lettering, which includes instruction and practice in a one-stroke freehand letter for working drawings. It is intended that the student shall acquire proficiency in the use of a letter applicable for shop and other drawings where a finished letter is not required but where rapidity and clearness are essential; thirty actual hours. Geometrical problems, which include the drawing of the problem in pencil and ink also a study of simple forms of projection in plan, elevation, and section; thirty actual hours. Cross sections, which includes practice in using drawing instruments in making the conventional signs of sections through different materials; nine actual hours. Tracing details, which includes the use of tracing cloth in making tracings from blue prints of standard drawings, and from pencil drawings; also making blue prints from tracings; twenty-one actual hours. Six sections. Assistant Professor POND, and Messrs. STAPLEY and HOTCHKISS.

4. **Drawing and Lettering.** Sophomores. For one half of the class, a credit of one hour the first term and three hours the second; and for the other half, a credit of three hours first term and one hour second term. Prerequisite course 1. The work is sub-divided and is taken up in the following order: lettering, which includes a study of, and practice in, different styles of letters, as Roman, Gothic, and stump, together with their combination into appropriate titles; seventy-five actual hours. Isometric drawing, which includes the principles involved in isometric projection, with practice in drawing from models and from dimensions; twelve actual hours. Line shading, which includes the shading of flat and curved surfaces by lines variously spaced and by lines of different thickness; eighteen actual hours. Detail and dimension drawing, which includes the tracing of typical dimension drawings and in making detail drawings from sketches, models, and from other drawings on different scales; forty-eight actual hours. Topographic signs, which include practice in the different kinds of standard topographic signs for mapping; twelve actual hours. Tinting and shading, which includes instruction in, and practice with, water colors, in the rendering of flat and curved surfaces, together with the use of crayon. Each student is required to take a number of plates and to become reasonably proficient in handling the brush and in using crayon; fifteen actual hours. Assistant Professor PARSON.

Topographic and Geodetic Engineering

10. **Elementary Surveying.** Freshmen. First term, credit three hours. Use of steel tape, level and transit. Fundamental surveying methods. Measurement of lines, angles, and differences of elevation. Land surveying; areas and plotting. Recitations, field work, computations, and mapping. Textbooks: Breed and Hosmer's Elementary Surveying, and Leland and Boothroyd's Area of Land. One recitation and two field or computation periods a week.

Eight sections. Assistant Professors LELAND and UNDERWOOD, and Messrs. LAWRENCE, MCCURDY, and STAPLEY.

11. **Advanced Surveying.** Sophomores. Throughout the year: first term, credit two hours; second term, credit four hours. Prerequisite course 10. City, topographic, hydrographic, mine, and geodetic surveying and field astronomy. Surveys of the United States Public Lands. Precise measurements. Transit and stadia; plane table; sextant. Soundings; stream measurement. Subterranean surveys. City planning. Earth volumes. Triangulation; base lines; precise leveling. Field determinations of azimuth, time, and latitude. Recitations, with field work after spring recess. Textbooks: Breed and Hosmer's Higher Surveying, Crandall's Geodesy and Least Squares, and Campbell's Practical Astronomy. Eight sections. Assistant Professors LELAND and UNDERWOOD, and Messrs. LAWRENCE and MCCURDY.

11a. **Advanced Surveying.** Primarily for students in forestry and landscape art. Second term, credit four hours. Prerequisite course 10. Topographic hydrographic, and geodetic surveying and field astronomy. United States Public Land Surveys. Precise measurements. Transit and stadia; plane table; sextant. Stream measurement. Topographic reconnaissance. Road location; circular curves. Triangulation for the control of local surveys; base lines. Field determinations of time, latitude, and azimuth. Recitations, field work, and plotting. Textbook: Breed and Hosmer's Higher Surveying. Four periods a week; field work after spring recess. Two sections. Assistant Professor LELAND and Mr. LAWRENCE.

12. **Elementary Surveying.** Primarily for students in Sibley College. Second term, credit two hours. A short elective course intended for those students outside of the College of Civil Engineering who desire work in surveying but who are unable to devote more than two hours to the entire subject. A knowledge of plane trigonometry is required. Use of surveying instruments. Tape measurements. Leveling. Problems with transit and tape. Stadia. Recitations, first half-term, field work, computations, and plotting, second half. Textbook: Breed and Hosmer's Elementary Surveying. Two periods a week. Two sections. Messrs. LAWRENCE and MCCURDY.

13. **Summer Survey; Topographic, Hydrographic, and Geodetic Survey; Camp.** Sophomores. Five weeks in June and July; credit six hours. Date of beginning to be announced in second term. Prerequisite course 11. Open also to students in forestry who have had course 11a, for whom the work is modified to meet their special needs. Practical experience in surveying under field conditions. An extensive topographic survey with the transit and stadia and the plane table, and a hydrographic survey of a portion of Cayuga Lake, are executed, and field maps are made. Triangulation and precise leveling control the topographic and hydrographic work. A base line is measured with invar tapes. Astronomic observations for azimuth, latitude, and time are made, and results computed. Each student takes part in all branches of the work. Field and office work six days and evenings a week. Assistant Professors LELAND and UNDERWOOD, and Messrs. LAWRENCE, MCCURDY and STAPLEY, and six others.

14. **Survey Computations and Mapping.** Juniors. Throughout the year, credit two hours each term. Prerequisite course 13. Adjustment of observa-

tions by the method of least squares. A complete set of the computations covering the field work of the previous summer survey, course 13, embracing base-line measurement, triangulation, and trigonometric and precise leveling. The work results in a set of permanent records, with the geographic positions, azimuths distances, and elevations of the various triangulation stations. The actual construction of final topographic maps of the area embraced in the preceding summer survey. The field sheets are combined for this purpose, reduced in scale from 1:4800 to 1:12000, and reproduced, using the triangulation system as a basis for the work. Recitations, computations, and mapping. Textbook: Crandall's Geodesy and Least Squares. Six sections. Assistant Professors LELAND and UNDERWOOD, and Mr. LAWRENCE.

15. **Least Squares; Adjustment of Observations.** Elective. Prerequisite, calculus and physics. First time, credit two hours. Lectures and recitations. The course is designed for students who have experimental investigations in view. Applications are made to problems in physics, astronomy, mechanics, hydraulics, surveying, etc., with some attention given to the derivation of empirical formulæ. Two hours a week, as may be arranged. Assistant Professor UNDERWOOD.

16. **Advanced Topographic Surveying.** Elective. Seniors and graduates. Prerequisite courses 11 and 13. First term, credit two hours. Economics of surveying methods. Surveys for special purposes, such as extensive construction work; storage and distribution of water for irrigation; earthwork on a large scale; lines of communication; topographic reconnaissance, etc. Phototopographic surveying. Lectures and reading. Two hours a week. Assistant Professor LELAND.

17. **Geodesy and Geodetic Laboratory.** Elective. Seniors and graduates. Prerequisite course 11. First term, credit three hours. A course for the consideration of special problems in geodetic work. Precise leveling. Deflection of the plumb line. Figure of the earth. Use and investigation of geodetic instruments and apparatus; circles, levels, micrometer microscopes, standards of length, thermometers, pendulums, magnetic apparatus, etc. Subject to arrangement to meet the special needs of students. Lectures, reading, discussions, and laboratory work. Three periods a week. Assistant Professor LELAND.

18. **Geodetic Astronomy.** Elective. Seniors and graduates. Prerequisite course 11. Second term, credit three hours. A study of the more precise methods of determining time, latitude, longitude, and azimuth, together with practice at the observatory in making and reducing the observations, including the determination of instrumental constants. Lectures, recitations, and observations. Three periods a week as may be arranged. Assistant Professors LELAND and UNDERWOOD.

Applied Mechanics and Hydraulics

20. **Mechanics of Engineering.** For sophomores in Civil Engineering. Throughout the year, credit five hours a term. Prerequisite mathematics, course 5. A study of the principles, and applications to engineering, of the mechanics of solids; as relating to the mutual actions, motions, pressures, strength, stiffness, and resilience of the members of structures and machines. Original problems form a prominent feature. Statics of a material point and of rigid

bodies. Centers of gravity. Chains and cords. Dynamics (kinetics) of a material point. Impact. Virtual velocities. Centrifugal and centripetal forces. Pendulums. Moment of inertia of plane figures and of rigid bodies. Dynamics (kinetics) of rigid bodies. Work. Power. Energy. Fly-wheels. Friction. Graphical statics of mechanism. Dynamometers. General theorem of work and energy applied to machines. Stresses and strains. Tension. Shearing. Compression. Torsion. Flexure. Elastic curves. Safe loads. Columns. Textbooks: Church's Mechanics of Engineering, and Notes and Examples in Mechanics, supplemented by other printed notes and problems. Lectures and recitations daily except S, throughout the year. Six sections. Professor CHURCH, Assistant Professors GEORGE and RETTGER, and Messrs. BRAUNER, C. CRANDALL and BUTTS.

21. **Engineering Calculations.** For sophomores in civil engineering. First term, credit two hours. Prerequisite, mathematics, course 5. This course consists of thorough practice in the mathematical processes used in the calculations made by civil engineers; as based on the mathematics of the freshman year and of the high school. Slide rule work is included, with some use of other computing devices. Two practice periods per week. Professor CHURCH and Messrs. ——— and ———.

22. **Materials Laboratory.** Sophomores. Either term, (one-half of the class each term), credit two hours. Must be preceded by, or taken with, course 20 and must be taken with course 25. Experimental determination of the properties of materials by mechanical tests. Study of testing machines, their theory, construction, and manipulation. Calibration of testing machines and apparatus. Commercial tests of iron and steel. Tensile, compressive, torsional, shearing, and flexure tests of metals and various woods with stress-strain observations. Tests of cement for fineness, specific gravity, normal consistency, time of setting, soundness, and tensile and compressive strength for neat and mortar mixtures. Tests of concrete aggregate, and of road material and paving brick. The course is planned to coördinate with course 25 and aims to supplement directly the study of the properties of materials by the actual handling of the materials and observation of their behavior under stress. Laboratory work three hours a week. Six sections each term. Assistant Professor MILLS, and Messrs. BRAUNER, BUTTS, and ———.

23. **Hydraulics.** Juniors. First term, credit five hours. (With topics in hydrostatics and pneumatics). Prerequisite, course 20. Fluids at rest. Hydrostatic pressure. Manometers. Strength of pipes. Pressure of water against walls and dams. Earth pressure. Immersion and flotation. Compressed air motors. Air compressors. Gas engines. Barometric leveling. Steady flow of liquids through pipes and orifices and over weirs. Fluid friction. Losses of head. Time of emptying vessels. Steady flow of water in open channels. Kutter's formula and diagrams based thereon. Steady flow of gases through pipes and orifices. Overshot, breast, and undershot water wheels. Theorems for flow in a revolving pipe. Impulse wheels (Pelton, Girard, etc.). Turbines and reaction wheels. Backwater. Theory of turbine testing. Other hydraulic motors and machinery. As part of the work of instruction, experimental demonstrations are given in the Hydraulic Laboratory to illustrate the principal phenomena of hydrostatics and hydraulics. Textbooks: Church's Mechanics of

Engineering, and Hydraulic Motors. Lectures and recitations, five hours a week. Six sections. Professor CHURCH, and Assistant Professors GEORGE, SCHODER and TURNER.

25. **Materials of Construction.** Sophomores. Either term (one-half of the class each term), credit three hours. Must be preceded by, or taken with, course 20, and must be taken with course 22. Textbook: Mills' Notes on Materials of Construction. The materials studied are: lime, cement, stone, brick, sand, timber, ores, cast iron, wrought iron, steel, and some of the minor metals and alloys. The chemical and physical properties, uses, methods of manufacture, methods of testing, and unit stresses of each material are considered, particular stress being laid on those points of importance to engineers. The work is planned to coördinate with the course in economic geology and supplements that work where necessary. Three recitations a week. Assistant Professors MILLS and WALKER, and Mr. BUTTS.

26. **Advanced Mechanics.** Seniors and graduates. Either term, credit three hours. Prerequisite course 20. Linear arches. Curved beams. Special cases of flexure. Problems in the mathematical theory of elasticity. Thick hollow cylinders and spheres. Plates. Castigliano's theorem of least work. Internal work and its derivatives. Recitations. Three hours a week. Professor CHURCH and Assistant Professor RETTGER.

27. **Testing Materials.** Elective. Seniors and graduates. Second term, credit three hours. Prerequisite course 22 and 25 or their equivalents. Special investigations of an advanced nature of the properties of structural units and the materials of construction.

Tests may be made upon full-sized sections in iron and steel, upon wooden columns, beams, and trusses; standard tests of paving brick and macadamizing materials; standard tests of cement and concrete aggregates; special investigations of the properties of concrete, plain and reinforced, upon full-sized beams and columns; tests upon the bonding strength of steel and concrete; tests upon riveted steel joints; tests upon wire cables, etc. Johnson's Materials of Construction and the publications of the American Society of Civil Engineers, and of the American Society for Testing Materials, are used as reference works. The aim of the course is to provide not only a knowledge of materials by observation of their behavior under stress, but also a knowledge of the technique of testing materials; a training in precise methods of observation and interpretation of results; and an appreciation of the relation of theoretical investigation to engineering practice. Advanced students are encouraged to make use of the laboratory facilities for special research. Seven and one-half hours a week as arranged. Assistant Professor MILLS, and Messrs. BUTTS and CONWELL.

29. **Engineering Problems.** Juniors, second term. Credit two hours. Prerequisite courses 20 and 23. The object of this course is to provide additional practice in using the principles and methods of applied mechanics, both of solids and fluids. A series of problems, such as occur in ordinary engineering practice, and covering a wide range of topics, is given out for solution. Computations and reports; six hours a week. Professor CHURCH, and Assistant Professors GEORGE, RETTGER, and TURNER.

Hydraulic Engineering

30. **Water Supply.** Seniors. Either term, credit three hours. Prerequisite course 23. Three hours recitation a week from assigned text and the working of several extensive problems. Problems assigned must be worked before credit can be allowed. Textbooks: Turneaure and Russell's Public Water Supplies, Hoyt and Grover's River Discharge, and pamphlets. About half of the term is devoted to the preliminary investigations for determining the available supply of water from drainage basin, general hydrology, methods of steam gauging, use of mass diagrams in study of storage, ground water resources, etc. The second half of the term is devoted to the methods of development, structures, and working conditions, particular attention being given to the requirements for a satisfactory fire protection, and the economics of pumped supplies. Applications of the methods of the text are made to particular localities, the topographic maps of adjacent cities and basins forming the bases of problems in design. Students specializing in the hydraulic group should arrange to be enrolled for the first term. Assistant Professors SEERY and WALKER.

31. **Hydraulic Constructions.** Elective for seniors and graduates. Second term, credit three hours. Should be taken after, or concurrently with, course 30. Two recitations and one computing period a week. The course is largely devoted to a study of the storage and conveyance of water, entering into a detailed examination of the methods and structures used, their design and construction, with special reference to public water supplies, power, irrigation, and navigation. Several extensive problems are worked, involving the preliminary examinations, explorations, and methods of surveys of a reservoir site, investigation of dam sites, design of high masonry dam by Wegman's Method, and the study of all the factors which may affect the stability and section of a dam. The economics of storage, cost of storage, manipulation of storage and pondage are also studied in numerical problems, the data being taken from actual projects. Earthen dams and embankments, flashboards, and movable dams are also considered. A review of the theory and practice of irrigation engineering and of the development of irrigation institutions occupies about half of the term, with some attention to the subject of river engineering as related to flood protection and the maintenance of navigable depths during low water, dredging, etc. Assistant Professor SEERY and Mr. C. CRANDALL.

32. **Water Power Engineering.** Elective for seniors and graduates. First term, credit three hours. Prerequisite course 23. Should be taken after, or concurrently with, course 30. Three recitations a week and the working of several extensive problems. General study of power development on a stream, the factors affecting the engineering and commercial feasibility of developing power and the value of a mill site; effect of pondage, storage, and load factor on capacity and equipment, and a detailed study of the characteristics of modern turbines, the selection of mechanical equipment, design of penstocks, and investigation of the speed regulation and governing of plant. Numerical applications of each of the important principles are made to existing plants or sites. Textbook: Mead's Water Power Engineering, supplemented by numerous assignments in engineering periodicals. Assistant Professor SEERY.

Experimental Hydraulics

41. **Hydraulic Measurements.** Elective. Seniors and graduates. First term, credit three hours. Prerequisite course 23. The experimental portion of the course is intended to familiarize the student with the manipulation, principles, precision, and adaptability of devices used in the measurement of flowing water. Experiments are made with orifices, nozzles, weirs, the Venturi meter, Pitot tube, ordinary water meters, friction head in pipes, current-meter rating, current meters and floats in open channels. The reports involve the principles and applications of logarithmic plotting including diagram construction. Three three-hour periods a week. Assistant Professors SCHODER and TURNER.

42. **Experimental Hydraulic Motors and Pumps.** Elective. Seniors and graduates. Second term, credit three hours. The determination of efficiency, capacity, and characteristics of hydraulic machinery. Three three-hour periods a week. Assistant Professors SCHODER and TURNER.

43. **Experimental Hydraulic Investigation.** Elective. Seniors and graduates. Either term, credit three hours. This course is intended for those students who desire to carry on experimental investigations in hydraulics under more immediate direction and supervision than prevails in case of thesis work. Written reports are required, but need not be typewritten nor bound in thesis style. These reports are kept by the Department. It is often possible and desirable for two students to work together on the same investigation. The field and scope of the investigation should be selected during the first two weeks of the term. For the experimental portion of the work the equivalent of three three-hour periods a week is required. Assistant Professor SCHODER.

44. **Advanced Experimental Hydraulics.** The facilities of the Hydraulic Laboratory are available for thesis work and for experimental investigations by graduate students; subject to special arrangements in each case. Professor HASKELL, and Assistant Professor SCHODER.

Municipal and Sanitary Engineering

50. **Sanitary Biology.** Juniors. Second term, credit five hours. Prerequisite Chemistry, course 6. Textbook: Ellis's Bacteriology, notes on Algæ and Protozoa.

The course includes a study of the principles of microscopy, bacteriology, and algology with special reference to sanitary engineering. Bacteriological and biological examinations of water supplies are made; and the identification and control of the various plant forms which render water supplies objectionable, or which indicate dangerous pollution, are taken up. Three recitations and two laboratory periods a week. Assistant Professor WALKER.

52. **Municipal Engineering.** Juniors. Second term, credit three hours. Prerequisite course 23. Sewer design and construction, and sewage disposal. Recitations, three times a week with occasional lectures. Problems (one each week), illustrating the matters taken up in the recitations, such as problems on sewage flow, both domestic and storm water, hydraulic problems of filling and emptying reservoirs, construction problems dealing with masonry foundations and reservoir walls and with various details of disposal plants. Text-

books: Ogden's Sewer Design, and notes on Sewage Disposal. Four sections. Professor OGDEN, and Assistant Professor WALKER.

53. **Purification and Control of Water Supplies.** Seniors and graduates. Second term, credit three hours. Prerequisite course 23. Examination of water, physical, chemical, and bacteriological; normal quality of surface and subterranean waters, with effects of storage; communicable diseases and water supplies; epidemics of typhoid fever and cholera with studies of etiology, etc.; purification of water, sedimentation, and coagulation; slow sand filtration, theory, construction, and operation, with examples; rapid sand filtration, theory, construction, and operation, with examples; miscellaneous purification processes, aeration, softening, iron removal, sterilization, distillation, and purification by chemicals. Professor OGDEN.

53a. **Sewage and Water Purification.** Seniors in the general group. First term, credit two hours. Prerequisite course 52. A general course dealing with the principles and practices of filtration both of water and sewage. Lectures, recitations, and problems. Professor OGDEN.

54. **Sewerage Works.** Seniors and graduates. First term, credit three hours. Prerequisite course 52. Three hours a week for 15 weeks, divided between lectures and recitations. Textbooks: Ogden's Sewer Construction, Kinnicutt, Winslow, and Pratt's Sewage Disposal. The work is upon the construction and operation of sewers and sewage-disposal works, illustrated by lantern slides and by reference to recent descriptions of sewage-disposal plants in the current literature. There are, generally speaking, three recitations or one week's work on each of the following topics: disposal by dilution (salt and fresh water); chemical precipitation; broad irrigation, with special reference to institutions; natural and artificial filtration beds; sedimentation and septic tanks; contact beds; and sprinkling filters. It is intended to differentiate this course from the junior work by making the latter chiefly a discussion of principles involved, while the senior course is a detailed investigation of the methods of construction with the reasons involved. Professor OGDEN.

55. **Sanitary Laboratory.** Seniors. Second term, credit three hours. Prerequisite courses 50, 52, and Chemistry 6. This course offers a practical demonstration of some of the topics considered in courses 52, 53, and 54. Studies of the qualities of water in streams, sewers, and in the city sewage settling tank are made by means of the usual tests for suspended solids, for dissolved oxygen and for oxygen consumed. Examinations of samples of sand are made for percentage of voids, for turbidity, for frictional resistance to water flow, and for efficiency as filters. Comparative tests of precipitants on various naturally and artificially polluted waters are carried out and losses of head in columns of sand are found. Measurements of velocities and grades in the city sewers and a study of their interrelation with sizes of pipes and depths of flow are made. Nine hours a week. Professor OGDEN.

56. **Municipal Engineering.** Elective. Graduates. A discussion and study of questions other than water and sewerage dealing with the health of cities. Lectures, reports, and readings. Three hours. Professor OGDEN.

57. **Purification of Water.** Elective. Graduates. Specific problems in water purification; control of watersheds; effect of sedimentation on waters of

different compositions; treatment of waters for particular requirements, such as removal of hardness, sediment, bacteria, etc. A report on some existing water system will be required from each student. Three hours. Professor OGDEN.

58. **Conference on Present Methods of Sewage Disposal.** Elective. Graduates. A critical study of the construction and operation of plants now in existence. Inspections and reports. Three hours. Professor OGDEN.

59. **A Laboratory Course for Graduates.** Devoted to some special problem of sewage or water, such as the operation of a water-filtration plant, a sewage-disposal plant, the purification of trade wastes, the value of disinfection, etc. Professor OGDEN and Assistant Professor WALKER.

Railroad and Highway Engineering

60. **Railroad Surveying, Construction, and Economics.** Juniors. Throughout the year, credit four hours a term. Prerequisite courses 10, 11, and 13. The campus field work includes the laying out of circular and transition curves; the fixing of grade lines, cross sectioning, and the staking out of masonry structures; the re-aligning of track and the laying out of turnouts. The Saturday field work consists of making the reconnaissance, preliminary, and location surveys for some ten miles of railroad. The topography is taken, the line is cross-sectioned and data are obtained for estimates of cost, including the structures and rights of way. The drawing includes a map and a profile of the located line and a plan for one or more structures. The earthwork is computed from the cross-sections, and complete estimates are made of quantities and costs, including structures. The recitations and lectures take up the field problems; the computation of earthwork; the cost of graduation, including tunnels, subgrade and track structures; track work; and the economics of railroad location and operation. Crandall and Barnes' Railroad Surveying and Railroad Construction, Crandall's Earthwork Tables, Beahan's Railway Location, mimeograph notes on economics including tonnage rating and electric railway run curves, and Gotshall's Electric Railway Economics, form the bases of the work. First term, two three-hour periods of field work a week, and alternate Saturdays. Six sections. Second term, three recitations a week, six sections; and one period of two and one-half hours a week in mapping, five sections. Professor CRANDALL, Assistant Professor BARNES, and Messrs. CONWELL and WHITE.

61. **Railroad Maintenance of Way.** Elective. Seniors and graduates. First term, credit three hours. Prerequisite course 60. The subjects treated are: track materials, with especial reference to the section, method of manufacture, and composition of steel rails; to the economics of tie preservation and the use of metal ties; and to the effect of quality of ballast upon maintenance. Machine and other methods of grading for second track; drainage; track laying both by machine and hand methods, ballasting and bringing new track to line and grade. Turnouts and switches: derailing switches; side tracks and yard tracks; sorting and terminal yards. Track maintenance; track tools; work trains. Action of car wheels on curves; widening of gauge. Double tracking; separation of grades; and improvement in grades and alignment. Textbook: Tratman's Railway Track and Track Work. Lectures and recitations three hours a week. Professor CRANDALL.

62. **Railroad Operation and Management.** Elective. Seniors and graduates. Second term, credit three hours. Prerequisite course 60. The course is based on Morris' Railroad Administration and Latimer's Railway Signaling, both of which are used as textbooks. Under organization the following subjects are treated: the general principles underlying organization and the effect of each on efficiency; principal departments of railway service with a brief outline of the work of each; departmental and divisional systems of organization, with examples on various roads and discussion of adaptability of each. The duties of officers and the work of the different departments are taken up in considerable detail. The most important laws affecting railroads are given in discussing the work of the legal department. Freight traffic, freight houses, classification yards, car service rules, accounting, etc., are among the topics considered under operation. Signaling and interlocking and train rules are also considered. Lectures and recitations three hours a week. Assistant Professor BARNES.

63. **Railroad Construction and Maintenance.** Special course for students in Sibley College. Second term, credit two hours. Preparation recommended: course 10 or 12. Second term. Textbook: Webb's Railroad Construction. Railroad Surveying; reconnaissance, preliminary survey and location: simple curves with methods of laying out; purpose and nature of transition and vertical curves. Railroad construction; earthwork, surveys, methods, and costs; rock work; culverts and minor structures; trestles and bridges; tunneling. Railroad maintenance; ballast, purposes, kinds, and cross sections; ties, materials and treatment; rails and rail fastenings; joints, switches and crossings. Railroad economics; statistics; cost of distance, curvature, rise and fall and change in rate or ruling gradient and tonnage rating. Attention is given to comparing capitalized cost of structures, changes in weight of locomotives, etc. Two recitations a week. Assistant Professor BARNES.

64. **Roads and Pavements.** Seniors; and juniors in the geodetic and sanitary groups. Either term, credit one hour. Prerequisite course 60. Examination of the methods of construction and maintenance of roads and pavements. Lectures and recitations. Professor CRANDALL, and Mr. CONWELL.

65. **Highway Engineering.** Elective. Seniors and graduates. Second term, credit three hours. Prerequisite course 60. Work consists of an examination of the prevailing methods of construction and maintenance of roads and pavements, starting with country roads of following types: earth, sand, sand-clay, water-bound macadam, etc.; treatment of macadam surfaces with bituminous and non-bituminous dust preventives and binders; the economics, construction, and maintenance of city pavements of following types: asphalt, bituminous concrete, concrete, brick, stone, wood block, etc. Problems in re-alignment, surfacing etc. Lectures and recitations, three hours a week. Professor CRANDALL, and Mr. CONWELL.

66. **Highway Laboratory.** Elective, Seniors. Either term, credit three hours. This course will require the student to make all the standard tests of highway materials. Rocks, sand, aggregates, non-bituminous and bituminous binders and dust palliatives will be investigated. The object of the course is to familiarize students with the methods of testing and the characteristics of the

materials used in road construction and maintenance. One lecture and two laboratory periods a week. Professor CRANDALL and Mr. CONWELL.

Bridge Engineering

71. **Structural Design.** Juniors. Throughout the year, credit four hours a term. Prerequisite course 20.

Structural Details. The recitations cover the graphic analysis of simple beams and roof trusses in chapters I and II of Merriman and Jacoby's Roofs and Bridges, part II. The computations and drawing include complete detail designs and working drawings of wooden joints to resist large tensile stresses, and of a wooden roof truss for given specifications. The object of the course is to show how to apply the principles of mechanics to the design of every detail of the simple structures named, and to study the forms and strength of joints and fastenings used in heavy framing. The computations required are to be arranged in systematic order in the form of reports. Reference book: Jacoby's Structural Details. First term for eight weeks. Computation and drawing, six hours a week.

Bridge Stresses. Stresses due to dead, live, and wind loads, initial tension, and impact. Panel loads and locomotive axle loads. Determination of the position of live loading for greatest stresses. Maximum and minimum stresses. Analytic and graphic methods are used. The principal types of simple trusses employed in modern construction are considered, in several cases both with and without counterbracing. Historical notes on truss bridges. The solution of many numerical examples taken from practice forms a prominent part of the class work. Each student is required to compute all the stresses in the main trusses and lateral bracing for a through Pratt truss railroad bridge which is to be designed subsequently. Textbook: Merriman and Jacoby's Roofs and Bridges, Parts I and II. First term. Recitations two hours a week for eight weeks, thereafter four hours a week.

Bridge Design. Computations and drawing for the complete design of a riveted railroad bridge of six or seven panels, the stresses for which were computed in connection with the previous study of bridge stresses. The computations to determine the sections of all members and of pins, pin plates, splices, and other details as well as of connecting rivets are to be written up in the form of systematically arranged reports. The drawings consist of general detail plans showing the location of all rivets as well as the composition and relation of all members and connections. The final report is to give a full list of shapes and plates, and a classified analysis of weight for the span. Textbook: Merriman and Jacoby's Roofs and Bridges, Part III. Second term. Computation and drawing, twelve hours a week. Professor JACOBY, and Messrs. BURROWS, KNOETTGE, and BEITZ.

72. **Reinforced Concrete Arch.** Seniors and graduates. Elective. Either term, credit three hours. This course may be substituted for engineering design, course 91f. Prerequisite course 20 and the first part of course 71. The design of an arch of reinforced concrete including its abutments and centering. The general form and proportions are determined by two preliminary investigations. The final investigations of the arch ring are made in accordance with the elastic theory, the live loading for maximum unit-tresses in the arch ring, as well as the direction and magnitude of abutment thrusts, being determined by means of

influence lines. The design is supplemented by several illustrated lectures on the different types of concrete arch bridges of recent construction, their principal details, methods of erection, and influence on design. Lectures, computation, and drawing, nine hours a week. Messrs. BURROWS and URQUHART.

73. **Higher Structures.** Elective. Seniors and graduates. Either term, credit three hours. Prerequisite courses 20 and 71. Determination of the loading and stresses in continuous girders and trusses, swing bridges, and metallic arches. The arches include arch ribs and trussed arches with three and two hinges respectively. Both analytic and graphic methods are used. The latter include displacement diagrams to find the deflections of trusses and the reactions of statically indeterminate structures, and the use of influence lines to find their loading and stresses. These studies are accompanied by historical notes on arches, drawbridges, and cantilever bridges. Textbook: Merriman and Jacoby's Roofs and Bridges, Part IV. Recitations, three hours a week. Professor JACOBY.

74. **Masonry and Foundations.** Seniors and graduates. Either term, credit three hours. Prerequisite course 20. Piles and pile driving, including timber, concrete, tubular and sheet piles; cofferdams; box and open caissons; pneumatic caissons for bridges and buildings, caisson sinking, and physiological effects of compressed air; pier foundations in open wells; freezing process; hydraulic caissons; ordinary bridge piers; cylinder and pivot piers; bridge abutments; spread footings for building foundations; underpinning buildings; subterranean explorations; unit loads. Textbook: Jacoby and Davis's Foundations of Bridges and Buildings. Recitations, collateral reading in engineering periodicals, and illustrated reports. Three hours a week. Professor JACOBY.

76. **Steel Buildings.** Elective. Seniors and graduates. Second term, credit three hours. Prerequisite courses 20 and 71. Mill buildings and tall steel buildings. Framing, trusses, beams, and columns. Eccentric loading, wind bracing, connections, and details. Roofs and floors. Weights and cost. Specifications. Design of a small mill building. Investigation of the effect of wind on a knee-braced mill building bent. Recitations, lectures, and reports. Six hours a week for eleven weeks, thereafter three hours a week. Mr. KNOETTGE.

77. **Concrete Construction.** Seniors and graduates. Either term, credit three hours. The purpose of this course is to continue the study of reinforced concrete construction and design begun in courses 20 and 25. While examples of actual construction are continually cited, special attention is paid to fundamental principles of design, to theoretical discussions, and to the interpretation of the results of experiments. It is the aim to give theory and practice equal weight, and to present the limitations as well as the advantages of this type of construction. Textbook: Turneaure and Maurer's Principles of Reinforced Concrete Construction, of which all chapters excepting Chapter VIII (on the arch) are studied. The subject matter covered is as follows: properties of the material; general theory; tests of beams and columns; working stresses and general constructive details; formulæ; diagrams and tables, building construction; retaining walls and dams; miscellaneous structures. At each recitation a problem is assigned, requiring about an hour's time to solve. One recitation and two drawing periods a week. Messrs. BURROWS and URQUHART.

Specifications, Designs, Etc.

89. **Cost Keeping and Management.** Elective. Seniors and graduates only. First term, credit two hours. An elementary course on the principles which govern the organization and management of laborers on construction; systems of payment, measurement of efficiency and cost keeping, with illustrative examples. Assistant Professor BARNES.

90. **Specifications and Contracts.** Seniors. Either term, credit two hours. Development of contract principles; agency, tort, and independent contractor; contracts of association, and of sale and transportation. Preparation of engineering contracts. Relation to commercial contracts. Practical suggestions for general condition clauses, as extras, contractor's risks, payments, arbitration, etc. Specifications and methods of studying them; skeletons of important examples of contracts and specifications. Practice in analyzing and in writing specifications. Acquisition, ownership, and conveyance of land; rights and liabilities in streams, surface and underground waters; property rights defined by boundaries; and determination of boundaries of land. Tucker's Contracts in Engineering is used as a text, and Wait's Law of Operations in Engineering Construction as a reference book. Lectures and recitations, two hours a week. Six sections. Professor CRANDALL and Assistant Professor BARNES.

91. **Engineering Design.** Seniors. Credit three hours. The student is required to make complete designs in one of the following subdivisions, subject to approval; hours to be arranged.

Engineering design for students in the general group (a) and in the geodetic group (b) may be taken in any one of the other groups by approval of the head of the department concerned.

(c) **Hydraulic Engineering.** Second term. Prerequisite courses 23 and 29. Design of hydraulic works, plants, and appliances, such as aqueducts, canals, irrigation works, locks, lift-locks, lock-gates, dams, reservoirs, stand-pipes, elevated tanks, systems of water works (gravity, pneumatic, or pumping systems), drainage works, power plants, water turbines, and other hydraulic motors and machinery, etc. Professor CHURCH and Assistant Professors GEORGE and RETTGER.

(d) **Sanitary Engineering.** First term. This course must be preceded by or taken at the same time as course 54, and may not otherwise be elected. The following problems assigned in 1909–10 indicate the scope of the work:

1. Computations, design, and detail drawings for the wooden forms needed for brick or concrete sewers of various diameters and forms of cross section.
2. Computations, design, and detail drawings for a pile foundation to support sewers from 3 to 10 feet in diameter.
3. Design and detail drawings for patterns of cast iron manhole covers.
4. Computations, designs, and detail drawings for flap valve as outlet of settling tank; the design involving a lifting device.
5. Design and detail drawings of a sewage screen, involving a device for raising screen for cleaning.
6. Computations, designs, and detail drawings for an inverted siphon for sewage flow. The problem involves a flushing gate and overflow as well as manholes.

7. Design of disposal plant for a small community as an asylum or school. Professor OGDEN.

(e) **Railroad Engineering.** Second term. Individual problems are assigned in conference with the student. These include: designs for track layouts and details, small depot buildings and freight houses, culverts, bridge masonry, subway construction; grade separation structures; water tanks, track and elevated, of steel, timber, or reinforced concrete; coaling plants, etc. Bills of material and estimates of cost are usually required. Professor CRANDALL.

(f) **Bridge Engineering.** Second term. Course 71 is required as general preparation for engineering design in bridges and buildings. Course 73 is required in preparation for designs relating to draw, cantilever, suspension, and metallic arch bridges. Course 77 is similarly required for designs of bridges and buildings in reinforced concrete. Course 72 may be substituted for engineering design. Professor JACOBY, and Mr. KNOETTGE.

92. **Thesis.** Seniors. Credit three hours. The thesis is intended to demonstrate the ability of the student for independent investigation, or his capacity to apply the fundamental principles acquired in this course to the study of some special problem related to civil engineering. The latest date for filing the subject with the Dean of the College is October 15th for the first term, and January 15th for the second term. The plan of work is to be submitted to the professor having charge of the subject, to whom also regular reports are to be made, showing the progress of the investigation. The latest date for presenting the completed thesis is June 1st. Regarding the approval of the subject or substitution for thesis see notes under the requirements for the four year course, page 13. A pamphlet containing instructions in regard to theses in Civil Engineering is available and should be consulted by students registered for this course.

Special and Graduate Courses

All the elective courses are suitable for graduate and advanced students, and may be taken by them in the regular classes. Other special courses will be arranged to suit the requirements of graduate students. These courses are intended to be pursued under the immediate direction of the professor in charge, the student usually being free from the restriction of the classroom, and working either independently or in conjunction with others taking the same course.